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CAMERA CALIBRATION NORTH GREENLAND

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Abstract:

This paper presents camera calibration results under inflight conditions based on an idea of Prof. Kölbl, which idea is further developed. The camera calibration refers to a block of 300,000 km² in Northern Greenland which was photographed in the summer of 1978 with a super wide angle camera from an altitude of 14000 meters (1:500000). Even under these extreme conditions the calibration method proves to be very efficient, yielding very high accuracy and not demanding any control points.

Four photos were used for the calibration measurements; two flown in East-West direction and two flown in North-South direction covering about the same area and both with a forward overlap of appr. 60%. About 100 random points were measured in stereo comparator in each of the 6 models formed by the 4 photos. The computation results show a systematic image deformation of a magnitude up to 25 µm determined with a RMSE at about 2 µm.

CAMERA CALIBRATION

NORTH GREENLAND

Introduction

In the summer of 1978 300,000 km² of Northern Greenland were photographed from a great height. The photos are to be used for an orthophoto map on the scale of 1:100,000. Control points will be produced by analytical aerotriangulation, using the same photos. Image scale is only 1:150,000, corresponding to a flying altitude of appr. 13,000 m (superwide angle). Under extreme conditions like these, non-predictable, systematic image deformations are likely to occur, for reasons like unverifiable refraction conditions or unknown influence of the camera window. To take care of these deformations it is desirable to make an inflight camera calibration.

Programme

The bundle adjustment system, ANA, developed at Aalborg University Centre, makes it possible to carry out a camera calibration without any control points, and using only parallax measurements, following the idea of Dr. O. Kölbl /4/. In this way you can determine the radial, the tangential, and the affine image deformations from measurements in only 3 to 4 photos. The deformations are included in the ANA programme as additional parameters.

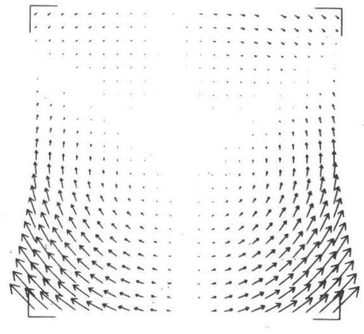
The deformation formulas can be described as follows:

Tangential deformation:

$$dt = r^{1.85}(t_1\cos\alpha + t_2\sin\alpha + t_3\cos 2\alpha + t_4\sin 2\alpha)$$

$$x'' = x' + dt/100000 \cdot \sin\alpha$$

$$y'' = y' - dt/100000 \cdot \cos\alpha$$



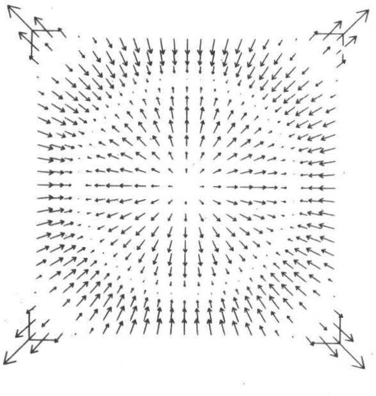
example

Radial deformation:

$$dr = r_1(r'^3 - r'r_o^2) + r_2 r'\left(\sin\left(\frac{r'\cdot\pi}{r_o}\right)\right)^2 + r_3\sin\left(\frac{2r'\pi}{r_o}\right)$$

$$x'' = x' + dr/100000 \cdot \cos\alpha$$

$$y'' = y' + dr/100000 \cdot \sin\alpha$$



example

Affinity:

$x'' = x'$

$y'' = y' - (af \cdot y' + sh \cdot x')/100000$

x' and y' are image coordinates in dm

$r' = \sqrt{x'^2 + y'^2}$

α = grid bearing

r_o = second (or first if only one) intersection of the radial lens distortion curve with the 0-axis of the coordinate system.

The parameters can be treated as elements as well as observations.

Measurements

Previous to the photo season I proposed a special photoflight for calibration purposes, consisting of a few cross-strips of only 3 to 4 photos.

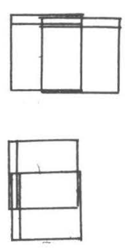
Unfortunately, it proved impossible to realize such a flight, but by a lucky chance, the last few photos of a strip happened to cover an area already flown at an angle of 90^{o}.

As ten days had passed between the two periods of photography and as the time of the day was different by some hours, it proved difficult to get a sufficient stereoscopic vision.

Six models were formed from four photos:

strip 1

strip 2



The ordinary models from the two strips + four combinations of photos from strip 1 and 2.

The two photos from strip 1 cover approximately the same area as the photos from strip 2.
Roughly 110 points per model were measured, with a regular distribution. The measurements took about 3 hours per model because of the bad stereoscopy. Otherwise, it would be half the time. The Carl Zeiss, Jena Stecometer was used.

Computation

The image coordinates were transformed (affine) on eight fiducial marks of the used Wild RC 10 camera. In the next step the coordinates were corrected for refraction and radial lens distortion, according to the calibration report.

The following a priori RMSE were assigned to the different types of observations:

obs	image coord.	t_1	t_2	t_3	t_4	r_2	r_3	af	sh
a pr. RMSE	(p=1) 6 μm	5	5	5	5	15	15	15	15

All observations for the additional parameters are given the value zero.
It is not possible to determine the parameter r_1 by this flight arrangement.

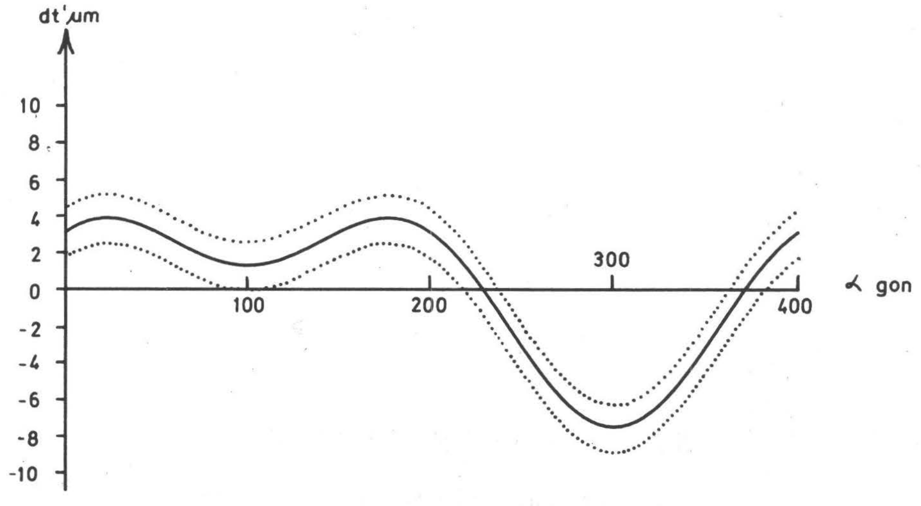
Results

The significant deformations were:

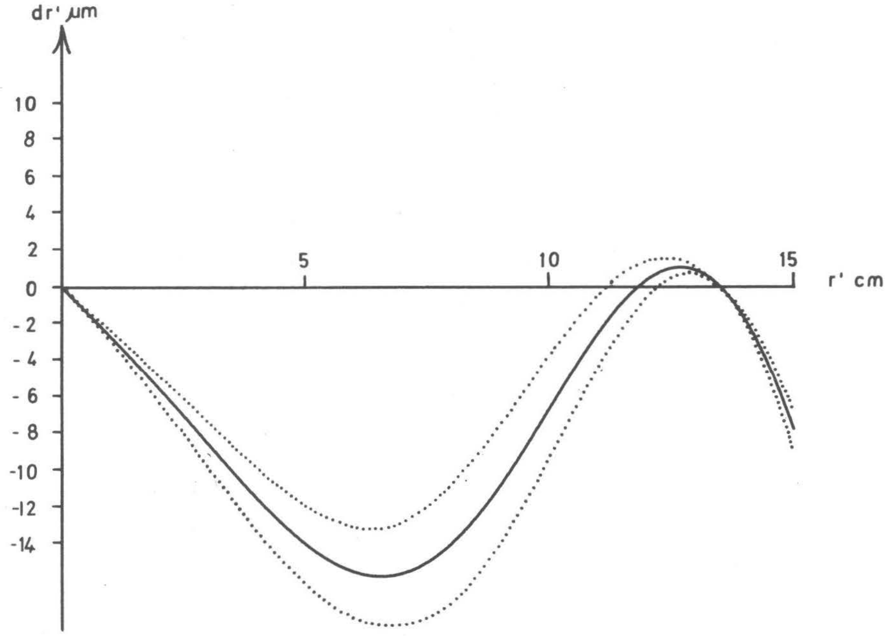
element	t_2	t_3	r_2	r_3	af	sh
value	4.4	3.1	-23.3	-5.7	-16.7	-12.5
RMSE	1.3	1.0	3.9	0.7	1.2	2.0

σ_o = 6.0 μm.

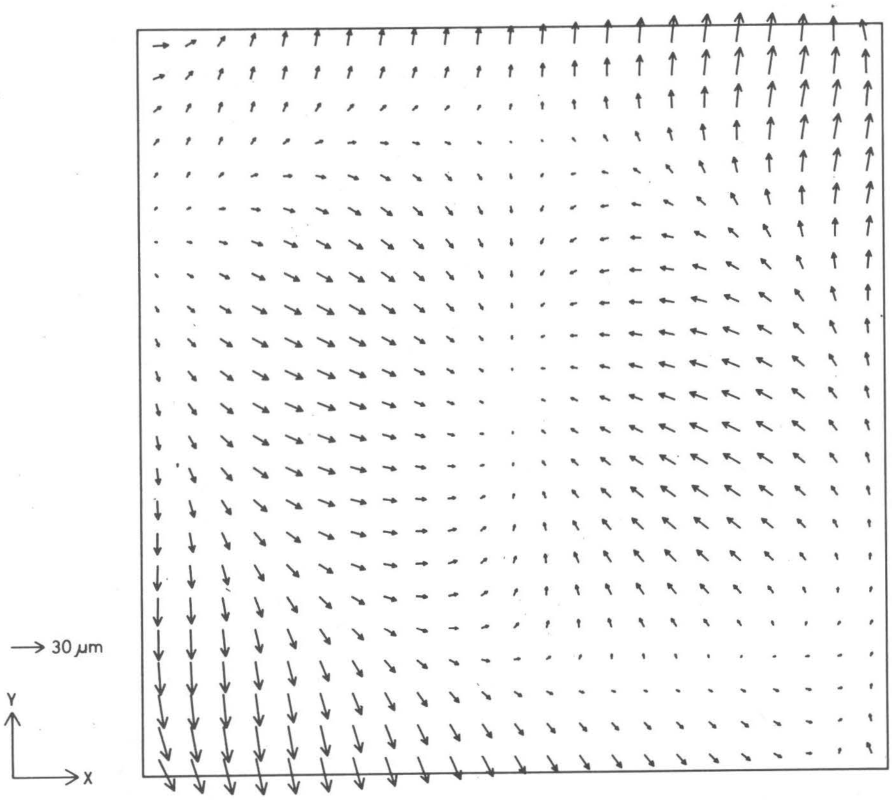
The value of r_o (see previous page) is put at 13.5 cm.



Tangential deformation at r' = 10 cm.

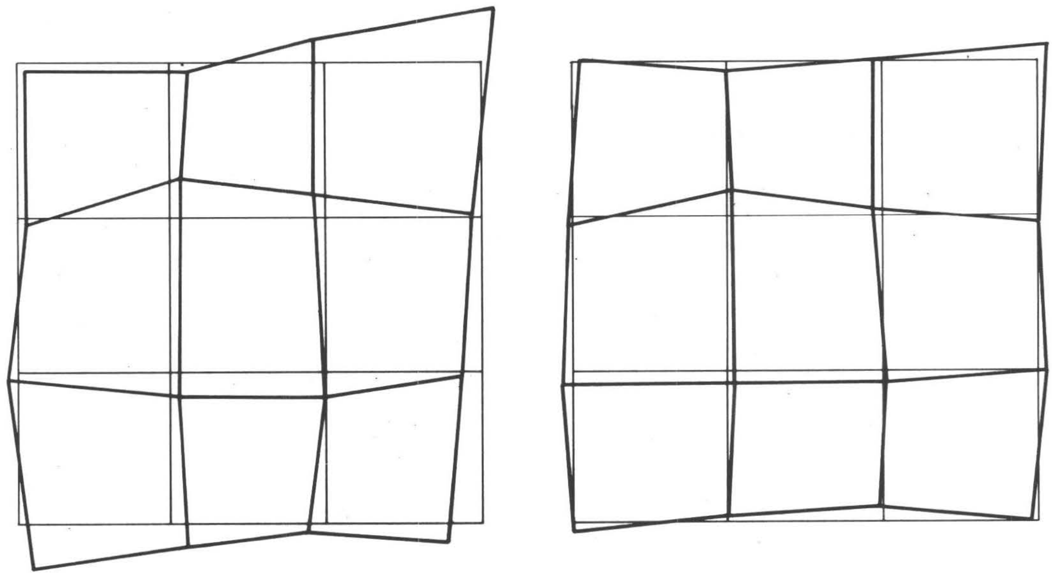


Radial deformation.



The total image deformation (6 parameters).

Plots of the residuals, from computations without and with the six significant parameters, are showed below. They are the mean of all photos.



Residuals without and with parameters.

How to use the results

Unfortunately, not all systematic deformations can be determined by this calibration method. It is not possible to find one of the elements (r_1) in the radial deformation as well as the position of the principal point or a correction of the camera constant.
Of these, r_1 can be of importance, whereas even large deviations at the principal point or in the camera constant give no essential deformation in cases, where the flying height is great compared to height differences in terrain.
r_1 is of special interest in Greenland, as it has a similar influence as the refraction and could compensate for a wrong value of the refraction coefficient.

In coming triangulations in Greenland I therefore propose to adjust with additional parameters. If the adjustment is made with the elements $t_1, t_2, t_3, t_4, r_1, r_2, r_3$, af, and sh, I would use the values found from the calibration as observations, with an a priori RMSE of 1 to 2. I would give r_1 the value of 0.0 and an a priori RMSE corresponding to the final value after the adjustment. This would then have to be done by iteration.

With few transfer points and few control points in the block, r_1 cannot be determined reasonably. It is thus important that the adjustment starts with well-conditioned blocks, to find a value for r_1 which can be used in later weak blocks.

From experiences with testfield computations with systematic errors of the same magnitude I conclude that with such corrections, the RMSE on adjusted points will decrease 50% or more, depending on the value of r_1.

Bibliography

/1/ D. Brown: Decentering Distortion of Lenses. Photogrammetric Engineering Vol. XXXII, p. 444-462, 1966.

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/4/ O. Kölbl: Tangential and asymmetric lens distortion, determined by self-calibration. BuL 43, p. 35-42, 1975.